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BOILER COMBUSTION CONTROL MAINTENANCE MANUAL(U)
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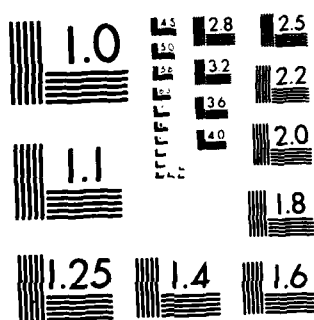
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NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

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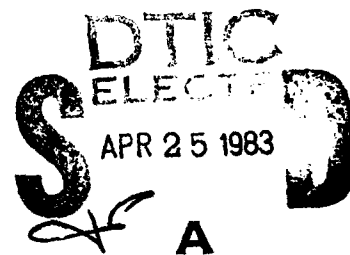
BOILER COMBUSTION CONTROL MAINTENANCE MANUAL

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March 1983

An Investigation Conducted by
ULTRASYSTEMS, INC.
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Irvine, California

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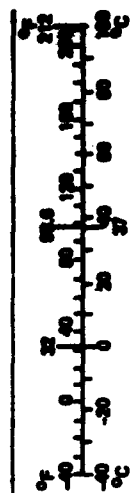
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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures			
When You Know	Multiply by	To Find	Symbol
LENGTH			
inches	2.5	centimeters	cm
feet	30	centimeters	cm
yards	0.9	meters	m
miles	1.6	kilometers	km
AREA			
square inches	6.5	square centimeters	cm ²
square feet	0.09	square meters	m ²
square yards	0.8	square meters	m ²
square miles	2.6	square kilometers	km ²
acres	0.4	hectares	ha
MASS (weight)			
ounces	28	grams	g
pounds	0.45	kilograms	kg
short tons (2,000 lb)	0.9	tonnes	t
VOLUME			
teaspoons	5	milliliters	ml
tablespoons	15	milliliters	ml
fluid ounces	30	milliliters	ml
cups	0.24	liters	l
pints	0.47	liters	l
quarts	0.95	liters	l
gallons	3.8	liters	l
cubic feet	0.03	cubic meters	m ³
cubic yards	0.76	cubic meters	m ³
TEMPERATURE (used)			
Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in. = 2.54 exactly. For other exact ac. conversions and more detailed tables, see NBS Mon. Publ. 280, Units of Weights and Measures, Price \$2.25, SD Catalog No. C12.10-280.

Approximate Conversions from Metric Measures			
When You Know	Multiply by	To Find	Symbol
LENGTH			
millimeters	0.04	inches	in
centimeters	0.4	inches	in
meters	3.3	feet	ft
kilometers	1.1	yards	yd
	0.6	miles	mi
AREA			
square centimeters	0.16	square inches	in ²
square meters	1.2	square yards	yd ²
square kilometers	0.4	square miles	mi ²
hectares (10,000 m ²)	2.5	acres	ac
MASS (weight)			
grams	0.035	ounces	oz
kilograms	2.2	pounds	lb
tonnes (1,000 kg)	1.1	short tons	st
VOLUME			
milliliters	0.03	fluid ounces	fl oz
liters	2.1	pints	pt
liters	1.06	quarts	qt
liters	0.26	gallons	gal
cubic meters	35	cubic feet	ft ³
cubic meters	1.3	cubic yards	yd ³
TEMPERATURE (used)			
Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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BOILER COMBUSTION CONTROL MAINTENANCE MANUAL

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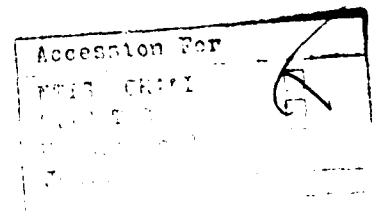
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INTRODUCTION

The Boiler Combustion Control Maintenance Manual provides general guidelines to the operating personnel in understanding the basic requirements for the establishment of a cost-effective maintenance program for combustion control of small industrial boilers.

The manual generally is confined to combustion control of oil or gas-fired boilers in the 60 million BTU per hour capacity range, but many of the concepts and principles discussed are applicable to boilers of any size and control systems other than combustion. Section 2.0 deals with general requirements for instrument maintenance. Section 3.0 provides guidelines for field checks of instruments and control devices in jackshaft, pneumatic, and electric combustion control systems. Section 4.0 provides general maintenance requirements for combustion control support systems. Sections 5.0, 6.0, and 7.0 deal with the maintenance requirements for major components normally employed in automatic control of jackshaft, pneumatic, and electric combustion control systems, respectively.

Section 8.0 discusses the Mobile Boiler Controls Unit concept and its possible application to the Navy small heating boiler program, and Section 9.0 is conclusions and recommendations.



2.0 INSTRUMENT MAINTENANCE

2.1 General

This manual specifically covers the maintenance of instruments and control devices normally included in jackshaft, pneumatic, and electric parallel positioning combustion control systems using steam header pressure as the controlled variable and identified in the "Theory of Operation Manual" as the most prevalent combustion control systems for small oil or gas-fired industrial boilers. However, the maintenance guidelines given below are applicable to all boiler control systems. Maintenance of peripheral equipment such as burners, fuel storage tank, combustion air fan, furnace casing and breeching which can affect combustion control in different ways is also addressed.

It should be recognized that it is not the intent of this manual to establish a fixed set of rules and procedures for boiler combustion control maintenance. Rather, the objective is to provide general guidelines that would assist the operating personnel in developing a satisfactory maintenance program for each boiler installation. The maintenance program for combustion control must be carefully thought out and evaluated for each individual boiler installation; it should be based on boiler size, service continuity, type and complexity of control system, fuel type, and maintenance cost.

In general it is necessary to conduct an annual overhaul of the boiler control and protective system. This will reduce the forced outage time and improve the boiler's operating efficiency.

2.2 Maintenance Facilities

Several options are available for maintenance facilities. They are: on-site instrument shop, a centrally dispatched mobile unit, an instrument service contractor or a manufacturers' shop. The selection of approach for each boiler installation is dependant on economies and the criticality of the boiler operation at its particular facility.

The test equipment requirements for a local or mobile facility would be similar and are listed as follows. In general all instruments should be high accuracy test quality.

Pressure Gauges - Ranges; 0-20, 0-60, 0-100, 0-500, 0-100

PSIG, 0-30"HG

Manometers - Ranges; 0-6", 0-12", 0-30"H₂O, 0-10", 0-30"HG.

Dead Weight Tester - 5-100 PSI

Pressure Regulators

Instrument Air Supply - 0-100 PSIG (bottled)

Thermometers

Temperature Bath

Potentiometer

Megger

Multimeter: ma, mv, V, Ohms, etc.

Recorders, multirange electric and pneumatic , miscellaneous fittings,

Tygon tubing, copper tubing, plastic tubing, etc.

In addition, instrument test stands, vises, benches and power supply will be required. These facilities should be separated from other work area for cleanliness and safety purposes.

Maintenance Records

A master set of drawings and instrument data sheets should be maintained for each facility. It is essential that these records are accurate and up to date for maintenance and safety. In addition, a copy of the manufacturer's service or instruction manual is required for each instrument or final drive.

Complete and detailed maintenance records as well as records of field checks should be kept. To be useful, the records should be correct and maintained well. All records of instrument repair and field checks should be dated and the respective instruments clearly identified, preferably by instrument number. A brief description of the nature of problem and the corrections made should also be included.

Complete maintenance records not only provide a readily accessible source of information for cost control, but also provide the following functions: (1) central source of original data and specifications; (2) complete history of alterations, range changes, performance under different operating conditions, replacement and repair; (3) cross comparison between different makes and models of instruments; (4) automatic recheck and preventative maintenance schedule; and (5) basis for estimating reliability and, in part, for predicting shutdown schedules.

3.0 GUIDELINES FOR FIELD CHECKS

3.1 General

The field maintenance overhaul program is divided into three phases. Calibration and Repair, Pre-operation Testing, and Dynamic Tuning. Although not specifically addressed in this manual, it is necessary to overhaul the boiler safety systems at the same time the combustion control is being checked out. Many of the procedures outlined here are also applicable to the safety systems. The boiler safety system includes, relief valves, high-low drum level switches, pressure switches, flame failure protection, purge protection, and other similar devices.

3.2 Calibration

This work will be done with the boiler shut down and isolated. Each instrument or final drive shall be calibrated in accordance with the manufacturer's instruction book for that specific item. Instruments may be calibrated in place, however, it is frequently easier to do the work in a shop using a test stand.

1. Power all transmitters from system power supplies before Calibration. Allow manufacturer's recommended warm-up time prior to start of calibration of device.
2. Calibrate pressure devices as follows:
 - a. Use certified dead weight tester, manometer or pneumatic calibration unit as applicable.
 - b. Adjust zero and span.
 - c. Check readings or output of device at 0 percent, 25 percent, 50 percent, 75 percent and 100 percent of input value.

3. Calibrate temperature devices as follows:
 - a. Use water bath or oil bath as applicable and certified test thermometers.
 - b. Adjust zero and span as applicable.
4. Calibrate level devices as follows:
 - a. Level controllers and liquid level switches:
 1. Use water column to establish water level in float chamber.
 2. Check direction of response of controller or switch points of liquid level switches.
 - b. Level transmitters or indicators:
 1. Use water column or pneumatic calibration unit, as applicable.
 2. Adjust zero and span.
 3. Check readings or output of device at 0 percent, 25 percent, 50 percent, 75 percent and 100 percent of input value.
5. Calibrate switches as follows:
 - a. Apply process input and adjust switch actuation points to required value.
 - b. Confirm switch makes/breaks with an electrical continuity check.
 - c. Adjust deadband if applicable.
 - d. Verify repeatability of switch actuation points after adjustments are completed.

6. Calibrate receiving devices, such as recorders, indicators, etc., as follows:
 - a. Apply applicable electrical or pneumatic input signals and power if required.
 - b. Adjust zero and span for each range.
 - c. Check readings or output of device at 0 percent, 25 percent, 50 percent, 75 percent and 100 percent of input value.
7. Calibrate transmitters and signal converters as follows:
 - a. Apply power, input signal, and process input, as applicable.
 - b. Adjust zero and span.
 - c. Calibrate as specified for the applicable process measurement.
8. Calibrate SO_2 , O_2 , and other analyzers in accordance with manufacturer's instruction.
9. Attach an approved calibration label to all devices after pre-operational calibration.
10. Inspect control valves, refinish seating surfaces as required, replace packing if necessary.
11. Inspect dampers and repair and adjust as required.
12. Stroke control drive and adjust the 0-100 percent and travel stops to match the input signal. Ensure all drives operate smoothly without chatter or sticking. Plot damper position versus control signal on increasing and decreasing signals to obtain hysteresis of dampers. Recondition drive and dampers when hysteresis exceeds 7-10 percent.

3.3 Pre-Operational Testing

1. Confirm that process sensing lines, air lines are connected and in good order. Lines should be blown out, then pressurized and bubble checked for leaks. Drive cylinders should be checked for rod packing and piston cup leakage.
2. Confirm that the instrument air power sources are adjusted to the correct level. Check the air to ensure that it is clean and dry. Check the dewpoint of the instrument air to assure proper dryness.
3. Confirm electrical power sources to transmitters, control drives, etc., are properly connected and adjusted.
4. Loop checkouts should now be made with the boiler shutdown.

The control system should be powered up and signals simulating process conditions applied to the field transmitters. The final drives should be observed for correct direction of travel. For example, apply a signal to the header pressure transmitter and observe the fuel valve opening when it is less than set point and conversely closing when it is greater than set point. This should be done for each control sub-loop.

3.4 Dynamic Tuning

It is recommended that an expert in boiler control tuning supervise the dynamic testing program.

Dynamic tuning takes place with the boiler operating. The tuning should be repeated at four load levels; 25 percent, 50 percent, 75 percent and full load. Adjustments will be made to the fuel, air

and feedwater controls to ensure rapid response to changes in demand, without hunting or dangerously overshooting. When tuning tests are conducted, the major process variables (header pressure, fuel, air, drum level) should be observed for response time, deviation and settling time. Although plant instrumentation may be used, high speed recorders will more clearly track the major variables. In addition, control signals may be recorded to identify the cause of control system malfunctions.

At the time boiler testing is being conducted, observers should monitor the furnace to ensure that complete combustion takes place at all times.

The boiler should be set at approximately 25 percent and allowed to stabilize. At this time a change in demand should be induced. This can be accomplished by changing header pressure set point or by placing equipment in services that will require a change in steam demand.

Adjustments should be made in the proportional band and reset rate, so that the controlled variables, air and fuel, change as rapidly as possible, without hunting or significant overshoot. In addition, based on visual flame monitoring and O_2 readings, adjustments should be made to the fuel-air ratio.

The testing and adjustments should be repeated at 50 percent, 75 percent and full load. Data should be taken to ensure that the boiler is operating on its design characteristic. The data includes: fuel, air, steam and feedwater flows, steam pressure, drum water level, all control signals, drive and valve positions, and flue gas O_2 . These data should be compared with results of previous tests and retained in the maintenance records.

4.0 PERIPHERAL EQUIPMENT MAINTENANCE

4.1 General

Proper maintenance of combustion control systems requires that combustion control support systems also be maintained properly. The support systems include oil and gas burner assemblies, fuel oil system, combustion air, and the furnace system. The maintenance requirements for major components of these support systems are discussed below.

4.2 Oil Burners

Oil burners may be classed as vaporizing or atomizing. The vaporizing oil burners are seldom used for industrial boilers, since they require distillate oils (No. 1 or No. 2 fuel oil); therefore, maintenance requirements for these are not discussed. Atomizing oil burners are divided into three types: steam, air, and mechanical. The mechanical type is sometimes called oil-pressure atomizing burner, since the required oil pressure is high (75 to 300 psig) and usually provided by use of gear type rotary pump sets complete with heaters for industrial boiler applications.

Atomizing oil burners should be checked visually at least once every shift to ensure there is no oil blockage and that the burner gets uniform, free-flowing oil. Note that sediment in oil caused by accumulation of sludge in fuel oil storage tank and dirty strainers can clog the burner nozzles.

In rotary cup atomizing oil burners, usually used on automatic-fired boilers, worn rims cause poor atomization; cups, with

worn rims, therefore, should be replaced. Cups can be protected from carbon forming on the rim by removing the cup when the burner is shut down and inserting a flame shield. Carbonized cups should also be replaced.

Mechanical atomizing nozzles are more subject to wear than other types of atomizing burners because of the high fuel oil velocity. Worn or carbonized mechanical atomizing nozzles should be replaced. Mechanical atomizing nozzles should be cleaned at regular intervals. In cleaning the nozzle, immerse the tip in light oil or kerosene to help loosen carbon accumulated at the tip and always use a wooden scraper to protect the surfaces being cleaned.

The preheat temperature must be correct for fuel and burner type. Good combustion requires that the preheat temperature be uniform.

4.3

Gas Burners

Gas burners generally require only routine maintenance. The important maintenance requirement for gas burners is that the gas connection is closed tight and gas header vented when the burner is shut down, so that there are no leaks.

4.4

Fuel Storage Tank

Fuel oil storage tank maintenance plays an important role in combustion control systems. Sludge should never be allowed to accumulate in storage tanks. Therefore, storage tanks should be cleaned on a scheduled basis; clean fuel storage tanks means relatively trouble-free burner nozzles. Also, strainers in fuel oil lines should be cleaned on a regular basis, if they are not of the self-cleaning type. Water should be drained from the tanks daily.

4.5 Combustion Air Fan

Fans generally are of the forced-draft type for small industrial boilers. They are usually motor driven through belt drives. Items that require periodic maintenance include proper belt tension, bearing lube system and lubrication requirements of the motor. The air damper on the fan outlet should also be checked periodically. Inlet filters should be cleaned on a regular basis or replaced, depending on the type of filter.

4.6 Furnace System

The furnace system includes the furnace casing, refractory surfaces, and stack. In forced-draft systems there usually is a slight positive pressure in the furnace causing small amounts of combustion gases to leak through cracks in the furnace casing and refractory surfaces. Therefore, both the furnace casing and refractory should be checked periodically for cracks and openings. Furnace casing sections with cracks should be repaired or replaced. Any large cracks in refractory should be cleaned out and filled. Small cracks in refractory can be sealed frequently by wash coating the refractory surface. Use high temperature bonding, air-dry type mortar diluted with water to the proper consistency for wash coating. Note that a telltail sign for cracks is a soot mark along the crack. Gaskets on handholes and inspection doors should be inspected periodically, and changed when necessary.

The breeching and stack should be inspected periodically and cleaned if necessary. The breeching and stack should be checked carefully for in-leakage of outside air. This is especially important for sections of breeching "upstream" of any oxygen analyzers or sample lines for flue gas analysis.

5.0 JACKSHAFT CONTROL SYSTEM MAINTENANCE

5.1 General

A jackshaft control system is shown in Figure 5-1, and it is usually operated electrically for small industrial boilers. A functional schematic diagram for such a system is shown in Figure 5-3. The maintenance of major control components shown in Figure 5-1 are discussed below.

5.2 Jackshaft

All bearings including those at drive rod ends should be lubricated at regular intervals, approximately once every two months.

All linkage should be checked for slack on a scheduled basis. Note that linkage rods should be "wiggled" in checking for looseness. Appreciable free movement will require the replacement of worn out bearings.

Adjustable set screws on the cam mechanism, shown in Figure 5-2, require lubrication at regular intervals, as well as checking for proper functioning.

5.3 Balance of Control Components

The maintenance requirements for the mechanical components of the master pressure controller, jackshaft drive unit, fuel control valve, etc., are similar to those for the pneumatic parallel positioning. The electric devices require only minimal maintenance.

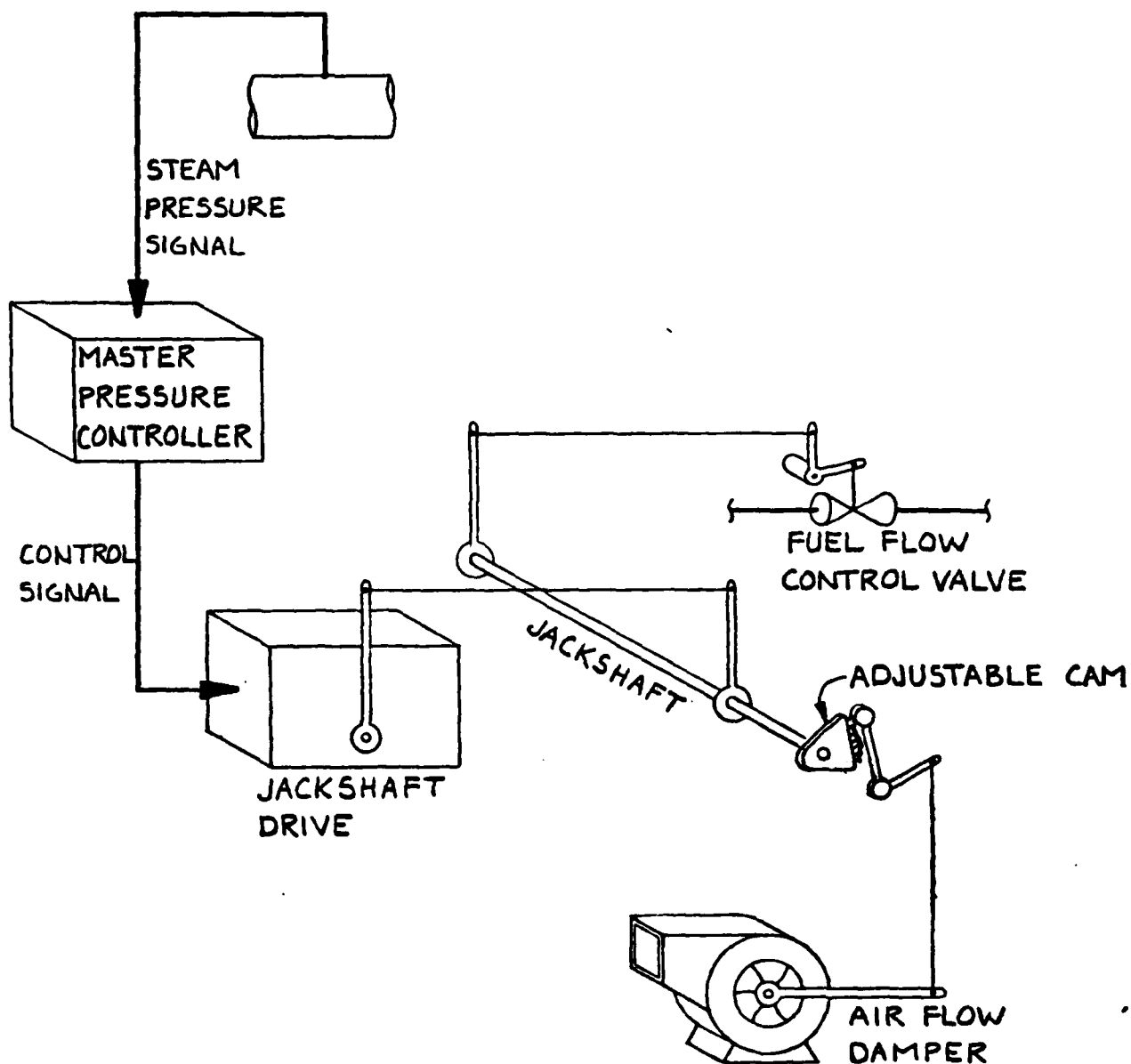


FIGURE 5-1 JACKSHAFT BURNER CONTROL SYSTEM

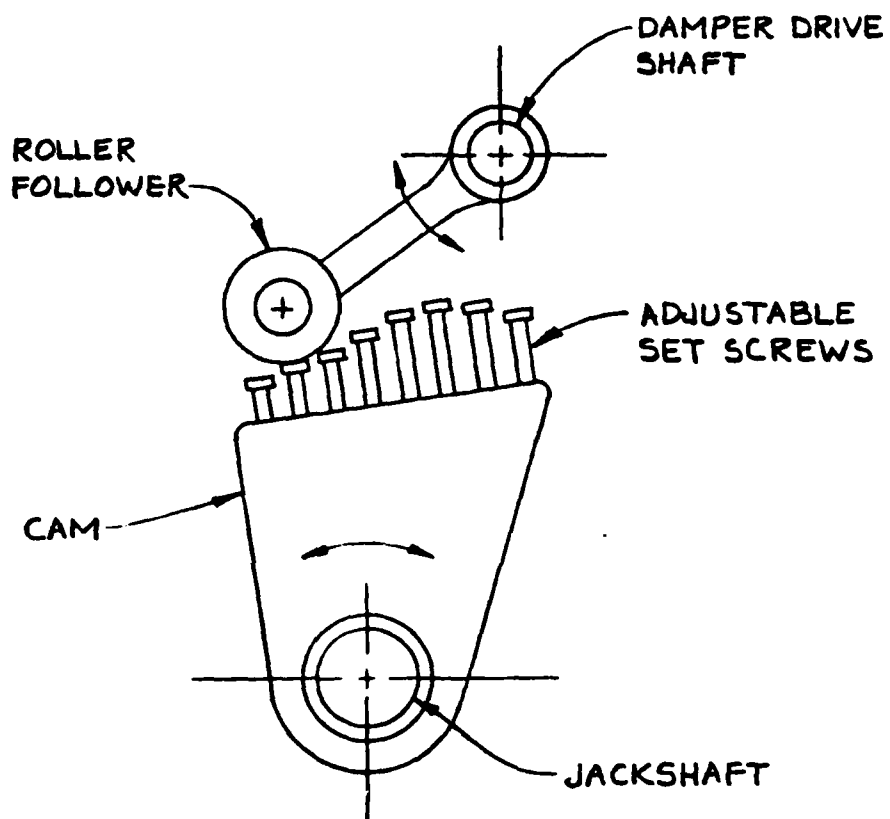


FIGURE 5-2 ADJUSTABLE JACKSHAFT
CAM MECHANISM

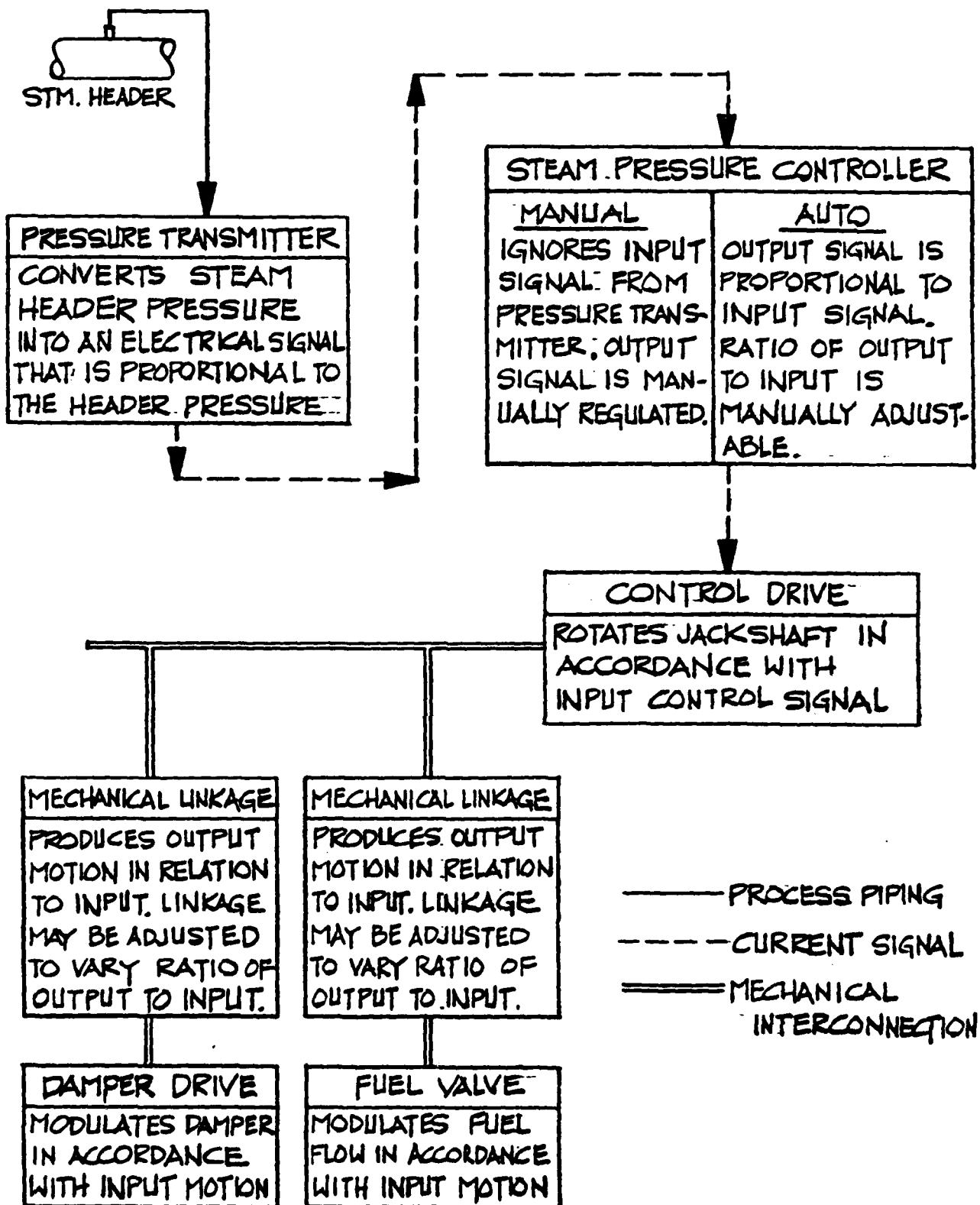


FIGURE 5 3 FUNCTIONAL SCHEMATIC DIAGRAM
JACKSHAFT SYSTEM

6.0 PNEUMATIC PARALLEL POSITIONING CONTROL MAINTENANCE

6.1 General

Maintenance requirements for pneumatic parallel positioning combustion control system are discussed. The requirements for pneumatic series positioning control components are similar. Figure 6-1 shows a pneumatic parallel positioning control system. A functional schematic diagram for this control system is shown in Figure 6-2. The maintenance of major components, shown in Figure 6-1, follows:

6.2 Master Pressure Controller

Figure 6-3 shows a master pressure controller instrument air piping diagram. The various internal adjustments of this component depends on the particular instrument make, and the manufacturer's instructions should be followed.

Routine maintenance of the master pressure controller consists of checking the output of the master pressure controller to see if it follows the steam header pressure changes. If it does not, it is probable that the steam pressure bellows in the master controller is broken. The manufacturer's instruction for bellows replacement should be followed.

6.3 Manual/Auto Station

The manual/automatic control station is normally located between the controller and the final control element, as shown in Figure 6-1. The maintenance basically involves the inspection of the poppet valve in the relay assembly for dirt or foreign matter in the inlet seat or exhaust seat. The latter is indicated by a continuous leak at the

exhaust port. Cleaning and replacement of inlet or exhaust seat of the poppet valve should be in accordance with the manufacturer's instructions. The transfer valve should also be dismantled and inspected during any overhaul.

6.4 Air/Fuel Ratio Controller

The air/fuel ratio controller normally controls the air damper positioner, but in some installations it controls the fuel valve positioner, however, the basic operation is the same. The routine maintenance of this component basically involves placing a few drops of light machine oil on the ball bearing fulcrum. The poppet valve should be dismantled and inspected during any overhaul.

6.5 Fuel Valve/Air Damper Positioner

The routine maintenance of fuel valve positioner and air damper positioner includes lubrication of the cylinder piston rod, side bars, and compensator. The lubricant should be a light machine oil. The compensator shaft should be lubricated with light grease. The pilot valve in each positioner should be inspected at regular intervals. When the piston fails to move quickly to the position required by incoming signal change, it indicates a malfunction of the pilot valve, which must then be repaired or replaced, as required, in accordance with the manufacturer's instructions. The receiving diaphragm should be replaced if ruptured or deteriorated. The replacement of the receiving diaphragm should be in accordance with the manufacturer's instructions.

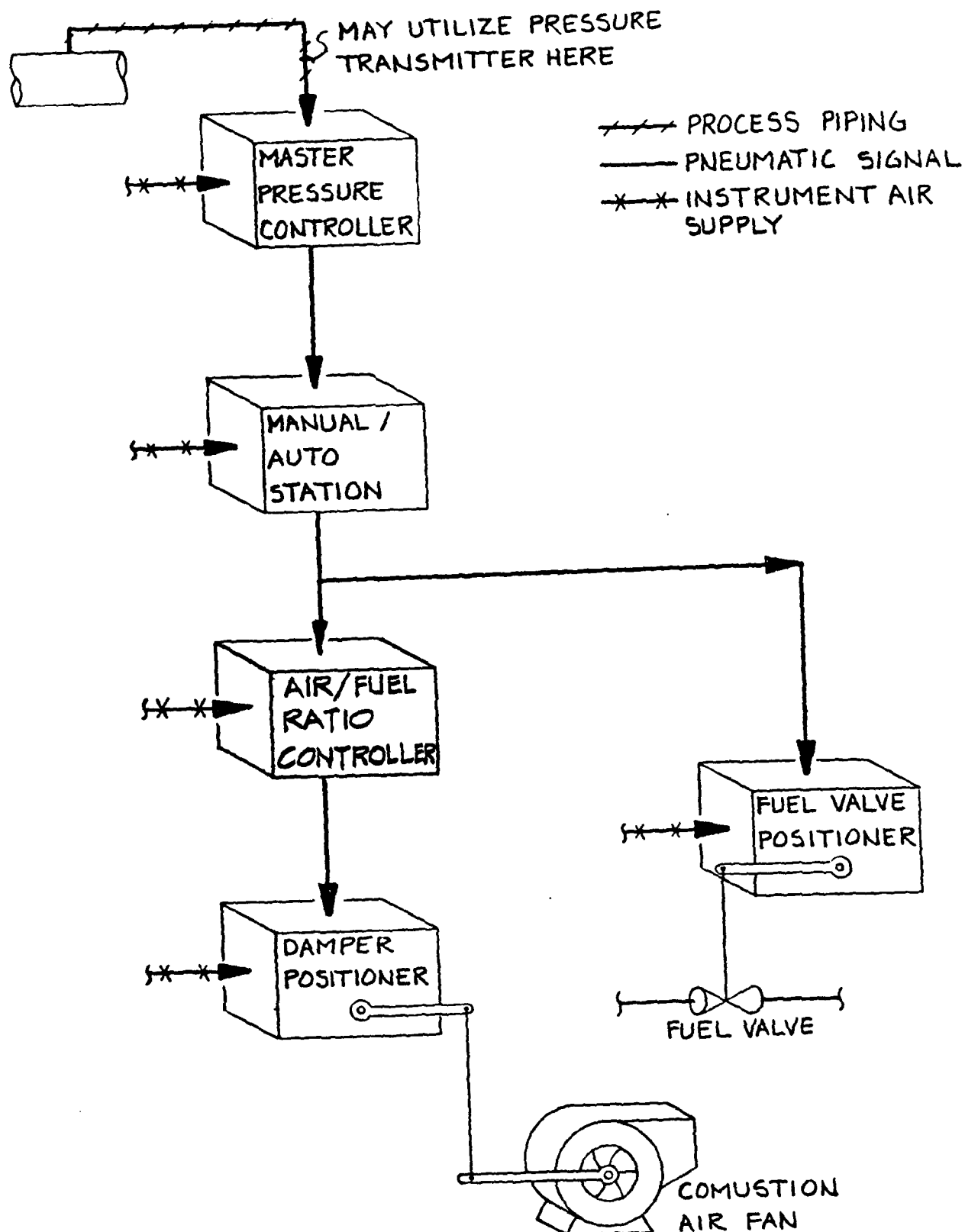


FIGURE 6-1 PARALLEL POSITIONING CONTROL SYSTEM (PNEUMATIC)

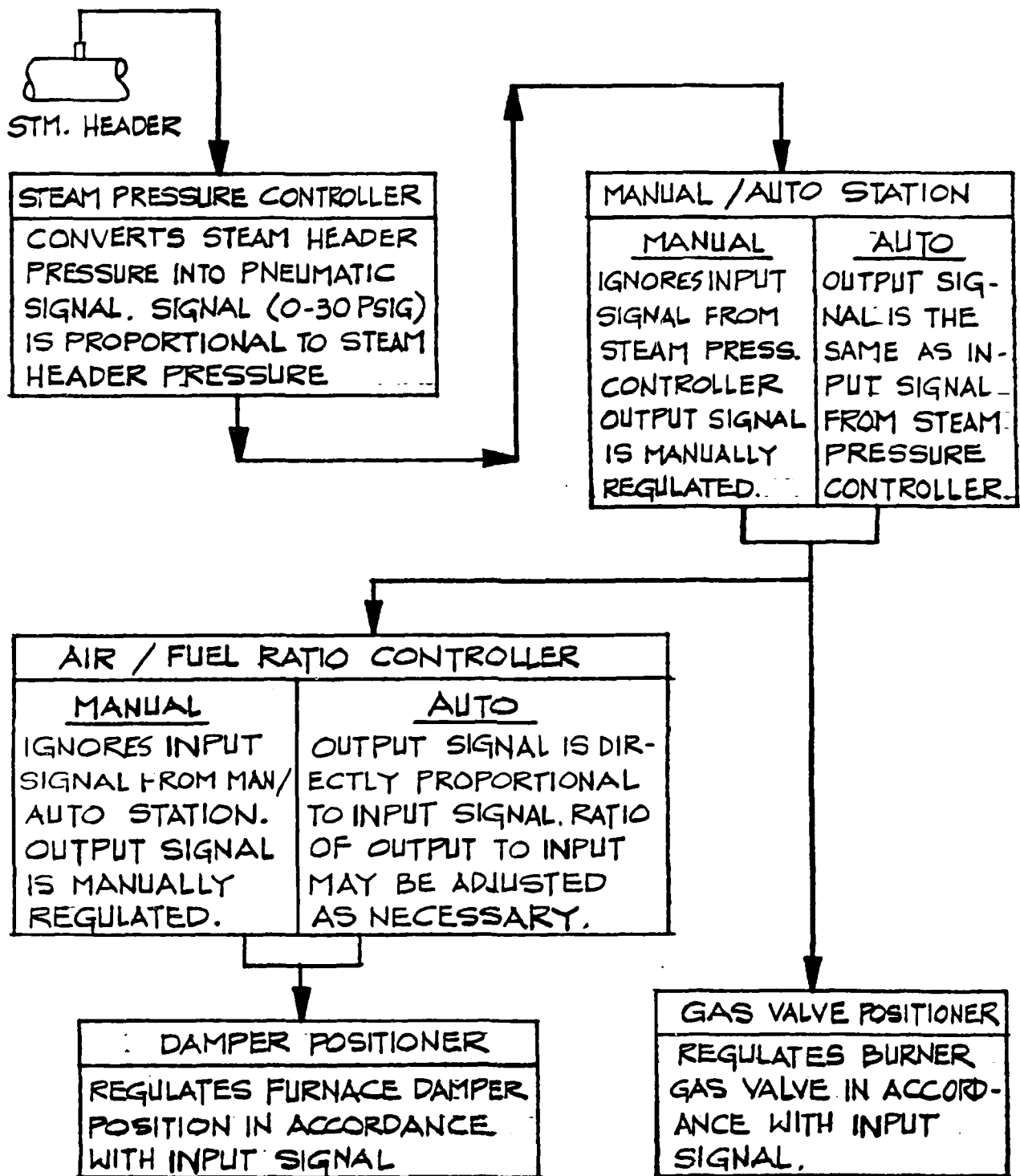


FIGURE 6-2 FUNCTIONAL SCHEMATIC DIAGRAM
PARALLEL POSITIONING SYSTEM
(PNEUMATIC)

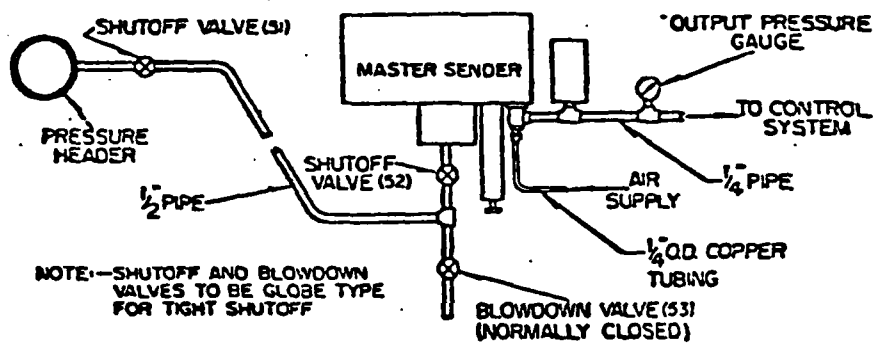


FIGURE 6-3
MASTER PRESSURE CONTROLLER
INSTRUMENT PIPING DIAGRAM

7.0

ELECTRIC PARALLEL POSITIONING CONTROL MAINTENANCE

Maintenance requirements for electric parallel positioning combustion control system are described in this section. The requirements for electric series positioning system are similar. Figure 7-1 shows an electric parallel positioning combustion control system. A functional schematic diagram for this system is shown in Figure 7-2. The maintenance requirements for the mechanical elements of the various control components are similar to, but less stringent, than those for the respective components described in Section 6.0 for a pneumatic parallel positioning combustion control system. An exception being the pressure transmitter, which is usually external to the master pressure controller. The pressure transmitter should be checked along with the master pressure controller if the controller output does not follow the steam header pressure changes.

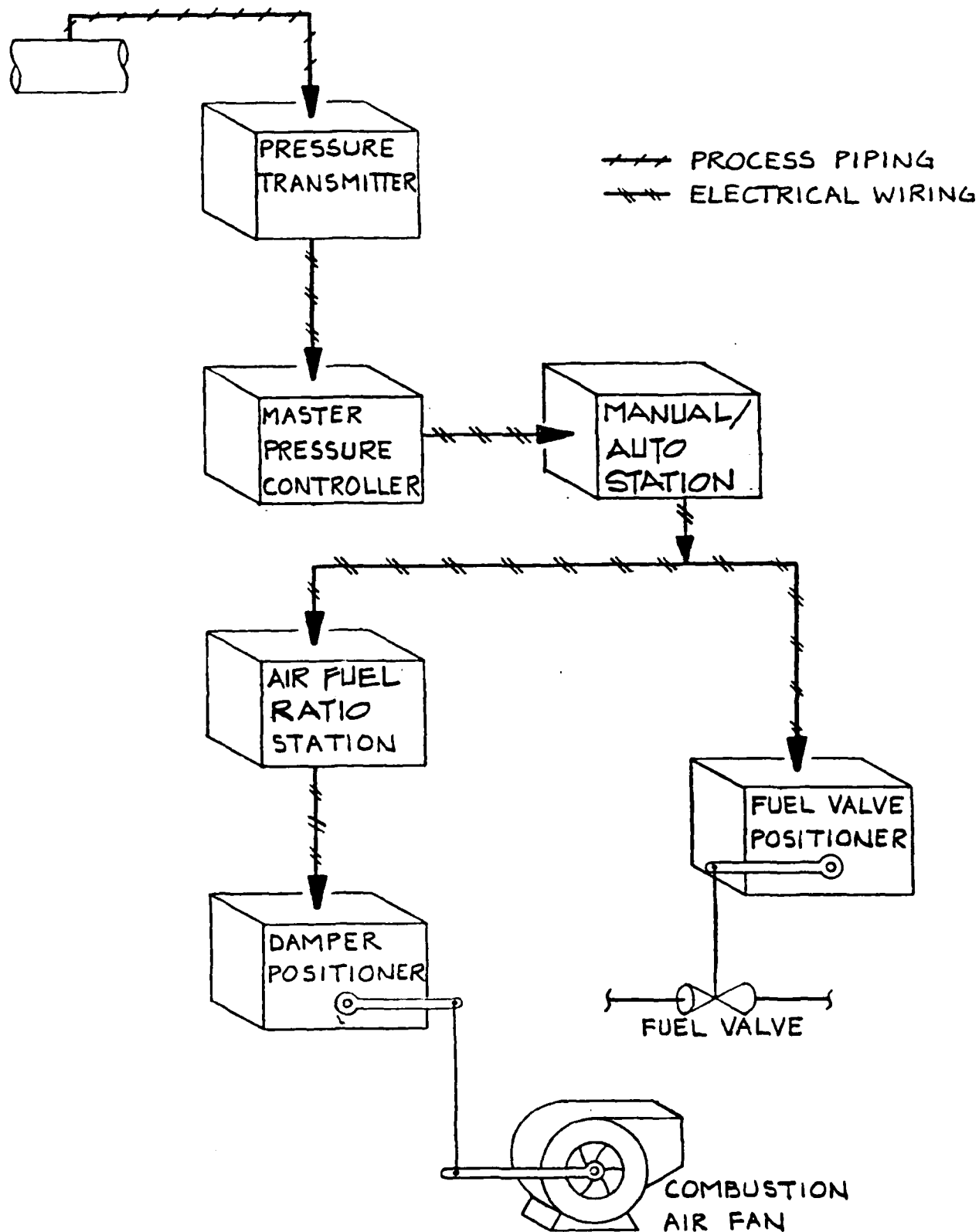


FIGURE 7-1 PARALLEL POSITIONING CONTROL SYSTEM (ELECTRIC)

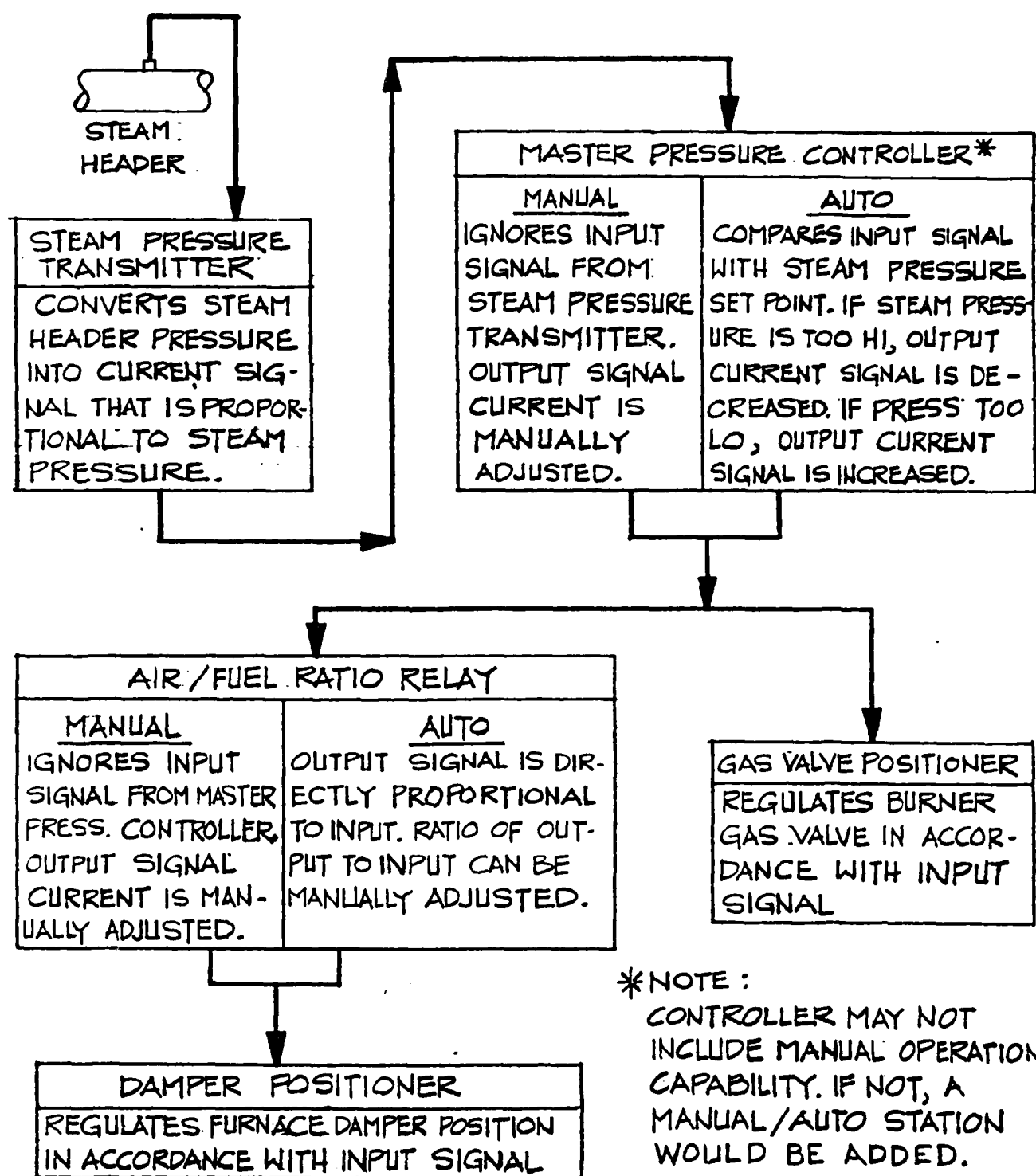


FIGURE 7-2 FUNCTIONAL SCHEMATIC DIAGRAM
PARALLEL POSITIONING SYSTEM
(ELECTRIC)

8.0 MOBILE BOILER CONTROLS UNIT

Should the Navy elect to do boiler controls maintenance in house, rather than contract it to vendors or service organizations, the mobile boiler controls unit approach should be considered. This approach will have merit for the Navy's small heating boiler controls maintenance requirement since its mobility will allow extended geographical coverage at minimum personnel and equipment cost. The suggested characteristics of such a unit would include:

1. Boiler tuning instrumentation.
2. Boiler controls diagnostic instrumentation.
3. Boiler controls maintenance tools and equipment.
4. Boiler control element test fixtures, etc.
5. Stock of selected spare parts and possibly spare elements for substitution during tests.
6. Boiler operator training aids.
7. Boiler controls maintenance technician training aids.

The foregoing materials would be installed and/or stored in a truck, trailer or van which would visit the Navy small heating boiler installations on either a scheduled or "as-required" basis. The mobile unit would be accompanied by at least the following personnel:

- a. A boiler operations and controls expert.
- b. A boiler controls maintenance expert.

It is assumed that these persons would be capable of conducting classroom and "hands-on" training of local personnel at each visit to a particular boiler site.

CONCLUSIONS AND RECOMMENDATIONS

A general approach to small heating boiler combustion controls maintenance has been presented which includes investigative methods for combustion control diagnosis. Comments on control element maintenance are included, as are some points to keep in mind regarding boiler maintenance on items that may effect boiler control.

A survey is recommended to determine on a gross basis which of the Navy's small heating boilers have combustion controls that should be updated, which ones require maintenance, and which ones are working satisfactorily. Following this survey, a plan for performing or having others perform combustion control system maintenance, should be developed. The following questions and procedures, as a minimum, need to be addressed:

1. Quantity and type of controls requiring maintenance, and on what time frame.
2. Method of effecting maintenance, i.e., vendors, contract services, local in-house, depot (Navy), or mobile unit.
3. Develop or procure boiler combustion control diagnostic procedures.
4. Develop or procure boiler combustion control element maintenance specifications and procedures.
5. Develop spare part and spare element requirements.

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